Enhanced Time-Based Proportional Control

FIELD OF THE INVENTION

This invention relates to time-based proportional control useful for chemical dosage control of water purification systems, such as the addition of chlorine to municipal swimming pools. The invention particularly relates to improvements in a time-based proportional control system for automating dosage control.

BACKGROUND OF THE INVENTION

Virtually all chemical dosage controllers marketed by U.S. Filter/Stranco within the last 10-12 years for use in the aquatic and industrial/municipal markets include a form of proportional chemical dosage control commonly referred to as Time-Based Proportional Control. Time-based proportional control has demonstrated usefulness for applications in cooling towers and other recirculated or batch systems that may experience dramatic loading swings.

Time-Based Proportional control was originally developed for use in spa applications where the chlorine demand will vary considerably due to small water volumes and the ratio of bodies/gallons of water in a spa. Standard on/off control for

this application was inadequate, as the only adjustment was the chlorine feed rate. On/off only control suffers from overshooting in either low loading situations, or inability to reach setpoint in high loading situations. A common method of addressing said overshooting is to manually adjust feed rates upwardly during the day and downwardly at night.

Time-Based Proportional control is basically a variation of on/off control which utilizes a relay output. Time-based proportional control utilizes a type of pulse width modulation effective to vary the duty cycle of the output relay on-time with respect to the deviation from setpoint. The duty cycle period is typically 30 seconds to one minute. As the sensor moves farther away from setpoint, the percentage of on-time per minute will increase. Conversely, the closer the sensor moves towards setpoint, the less the feeder operates per minute. Whenever the sensor of the controller exceeds setpoint, the feeder is always off. Recent improvements to this control have been the addition of an offset to keep the feeder from completely stopping until the setpoint is exceeded by some value and the ability to change the duty cycle period.

A deficiency of the time-based proportional control function is that it fails to operate efficiently because it

never reaches setpoint on high loading days-when it is needed the most.

Thus, what is lacking in the art is an ability to incorporate a form of deviation compensation which could be described as time-based proportional control with automatic offset, to thus include a functionality, having a relatively small number of resets per minute and a low sensitivity which, when incorporated therein, would eliminate the systems failure to achieve setpoint on high loadings days.

SUMMARY OF THE INVENTION

The instant invention is a device and method for its use which includes the addition of a type of deviation compensation function which, in effect, provides an automatic offset ability which is effective for automatically adjusting the offset used in time-based proportional control. In practice actual offset adjustment is not always necessary. An equivalent result is achievable by including a mathematical incrementation of the duty cycle ratio. Inclusion of this improvement finds particular utility in situations like public pools where daily bather load varies depending on weather and other unpredictable factors.

Accordingly, it is an objective of the instant invention

to teach a method and device to enhance time-based proportional dosing of chemical additives by inclusion of a form of deviation compensation effective to approximate an ideal proportional control response.

It is a further objective of the invention to provide an ideal proportional control response by providing time based proportional control with automatic offset.

It is yet another objective of the instant invention to provide an ideal proportional control response by mathematically incrementing the duty cycle ratio.

It is a still further objective of the instant invention to provide ideal proportional control response by including integration of a measured signal.

Other objectives and advantages of this invention will become apparent from the following description taken in conjunction with the accompanying drawings wherein are set forth, by way of illustration and example, certain embodiments of this invention. The drawings constitute a part of this specification and include exemplary embodiments of the present invention and illustrate various objects and features thereof.

BRIEF DESCRIPTION OF THE FIGURES

Figure 1 is a graphical representation of prior art on/off control;

Figure 2 illustrates a typical on/off response curve;

Figure 3 graphically illustrates chemical wastage;

Figure 4 illustrates typical time-based proportional control;

Figure 5, illustrates the ideal response of a Time Based Proportional control system;

Figure 6 illustrates actual proportional control response with loading;

Figure 7 shows the programmed response of the Time Based Proportional control with the addition of Integral response;

Figure 8 is illustrative of the expected time-based proportional control with integral response in a typical HRR (High Resolution Redox) loading situation;

Figure 9 is illustrative of a feed up example utilizing timed base proportional logic;

Figure 10 modifies the prior art proportional logic mode of operation by including integration of a measured signal.

DETAILED DESCRIPTION OF THE INVENTION

Time-Based Proportional control devices, for example devices available from USFilter/Stranco under the name STRANTROL are an improvement of the On/Off control method.

On/Off is commonly used for simple automatic process control.

To explain the improvement Time Based Proportional control provides, it is best to first explain the On/ Off control method and its limitations:

Note that in Figures 1-8 the X-axis represents time and the Y-axis represents the stated value but is not unit dependent, e.g. for proportional band width (PB), the graphical analysis is independent of whether the setpoint units are in mV, pH, microsiemens, or the like.

Now referring to Figure 1, On/Off control, as the name implies, has only two control states, ON and OFF. A disinfection control system feeding a chemical like Sodium Hypochlorite can be used as a good example. When the measured signal (HRR) is below the desired value (setpoint), the controller output is ON and stays on continuously until the measured signal meets or exceeds the setpoint. When the measured signal equals or exceeds the setpoint, the controller output changes to the OFF condition and the chemical feeder stops adding more chemical to the system.

With respect to specific chemical feeders, the controlling limitation is the ability of the feed system to tolerate a power on duty cycle of fractions of a minute. High current rotational motor driven pumps can be damaged by

short duty cycles such as 30 seconds on, 30 seconds off. Motor-operated ball valves also cannot tolerate short duty power applications. US Filter/Stranco utilizes Time-Based Proportional (TBP) control to regulate their patented CHF-150 Calcium Hypochlorite feeder, along with a variety of brands of solenoid-motor diaphragm metering pumps. It is likewise within the purview of the instant invention to utilize time based proportional control to regulate peristaltic pumps from various manufacturers, solenoid valves that control water flow to venturi-type ejectors used to feed gaseous and liquid chemicals into water such as Chlorine, Sulfur Dioxide, Carbon Dioxide, and the like. Additionally, the use of TBP to control special duty solenoid valves that operate under pressure or vacuum to control chemicals (liquid and gaseous) fed, for example, to US Filter/Stranco's patented WATER CHAMP gas induction feeders, CO_2 feeders and the like are also contemplated.

As further illustrated in Figure 2, a typical on/off response curve is exemplified. The limitations of this control method are the system lag time and loading. In most industrial applications, ON/OFF control always overshoots the setpoint both on the increase and decrease of the measured signal. In the disinfection control example, when the HRR

exceeds the setpoint, the chemical fed to the system stops, but the mixing and distribution of the chemical fed during the lag time continues to increase the system's HRR. This sinusoidal response is very typical for this control method. Restricting the flow rate of chemical to the system can minimize the sine wave amplitude, however during high load events the chemical feed will be unable to meet the demand. The result is that some overshoot is accepted as the limitation of an inexpensive (and simple) control method.

As particularly illustrated in Figure 3, the height of the first peak will vary based upon the response time of the system, and the initial deviation from setpoint. The areas under the curve (above the setpoint) also represent wasted chemical.

Now referring to Fig. 4, typically Time Based Proportional response improves upon the simple control method by adjusting the feed rate of chemical based upon the measured signal's deviation from setpoint. In Time Based Proportional control, the ON time per minute of the output relay is varied based upon the measured signal's distance from setpoint. This is very similar to the P of P. I. D. control, except the output is not continuous. The advantage can be seen using the same disinfection example. If one

turns the Sodium Hypochlorite pump on for 10 seconds and off for 50 seconds when you are only 1 mV below the desired HRR, the rate of HRR rise will be far less per minute and the overshoot will be minimal. Figure 4 illustrates the output feed ratio of time based proportional control throughout the proportional band. The benefit of time based proportional control is a more consistent disinfection rate (less corrosion and fouling), and chemical is conserved because chemical is not being fed to exceed the desired disinfection rate.

With reference to Figure 5, the ideal response of a Time Based Proportional control system is illustrated.

Proceeding to Figure 6, while Time Base Proportional control is an improvement over ON/OFF control, it still has certain limitations. With large fluctuations of loading, Time-based proportional control may not increase the output enough to compensate. Using the disinfection example again, when an increased loading condition occurs, the controller using Time Based Proportional control will proportion the output to increase the Sodium Hypochlorite feed rate to the system. But as the HRR starts to rise, the controller will reduce the output at the same ratio as the previous loading. The result is a setpoint that may never be achieved, because

it now takes more Sodium Hypochlorite to maintain the same HRR (due to loading).

In order to address the inability of a time based proportional control system to achieve setpoint during a loaded condition, the instant invention incorporates an additional response into Time-based proportional control that will compare the measured signal to the setpoint with respect to time, and increase or decrease the output time ratio (duty cycle) to compensate for loading as needed. This is accomplished by increasing or decreasing an offset value applied to the control setpoint.

Figure 7 depicts the programmed response of the Time Based Proportional control with the addition of selected time duration response. The rate of change would be tied proportionally to the deviation from setpoint and may be adjustable with software. The time base used for the selected time duration response would be different (usually longer) than the proportional time base, is generally set forth as a multiple thereof, and can also be adjustable. Typically, in the recirculated systems currently controlled by time based proportional control, the selected time duration response time base would about 5 minutes.

Referring to Figure 8, the figure is illustrative of the

expected time-based proportional control with selected time duration response in a typical HRR loading situation as described in the text above. As is readily appreciated, this curve closely mirrors the ideal proportional control response as set forth in Figure 5.

Now referring to Figures 9 and 10, the inclusion of integration logic within the standard proportional logic feed up is exemplified. Figure 9 is illustrative of a feed up example utilizing timed base proportional logic, absent selected time duration response logic. Figure 10, specifically the area within the block 1010, modifies the prior art proportional logic mode of operation by utilizing a form of deviation compensation, for example by including selected time duration response logic, which may be manifested as integration of a signal, so as to achieve an automatic offset of the time based proportional control function. The signal must first be verified to be residing within the chosen proportional band width, and it must be further confirmed that the signal is within a particular hysteresis value about the desired setpoint. If the signal is found to be outside of the hysteresis value of setpoint, then a determination must be made as to whether the signal falls within the category of being either steady or

retreating from the setpoint during the integral time duration. If the determination is affirmative, then a change in the offset is carried out based upon selecting a value, herein termed the "offset sensitivity value" or OS and multiplying it by the value of deviation from setpoint. Inclusion of this subroutine idealizes the time based proportional response.

Ranges of typical values for the calculation of the formulas are as follows:

Proportional Band Width (PB) is typically 30 or 60 mV with an allowable range between about 5 and 500 mV. .50 pH units is typical with an adjustable range between about .10 and 5.00 pH units. From about 100 to 500 microsiemens is typical with an adjustable range between about 10 and 5000 microsiemens.

Time Base(TB): typically 30 or 60 seconds with an adjustable range between about 15 and 600 seconds

Signal(SIG): HRR typical range is 0-1000 mV with an instrument maximum range of -1500 to +1500, pH typical control range of 2-12 pH with an instrument maximum range of 0.00-14.00 pH. Conductivity typical range is 1000-5000 microsiemens with an instrument maximum range of 0-10,000 microsiemens.

Setpoint(SP): HRR is application dependent but is generally within the range of about 150 to 780. The pH will typically be

between 2 and 12 pH with the greatest majority of applications (90%) within the 6.00-9.00 pH range. Conductivity setpoints are generally between 1000 and 4000 microsiemens.

Hysteresis values for HRR are 0-10 mV with .02 typically used. Hysteresis for pH is typically .02 or .1 with a range of 0.00-1.0 pH. Conductivity hysteresis is usually 10 but can range from 0 - 1000.

Offset Sensitivity Value (OS) is a percentage or fractional percentage with a range between 0 and 100%. The Setpoint Offset Value (SOV) is calculated by taking the Sustained Deviation From Setpoint (SD) as a fractional percentage of the Proportional Band (PB) multiplied by the Offset Sensitivity Value (OS) times the Proportional Band, according to the formula: SOV = (SD/PB)*OS*PB

Example: SD= 10 mV; PB = 30 mV; % of PB =.33; if Offset Sensitivity Value = 1.00 then setpoint offset would change by .33 * OS * 30 or 10 mV. If OS=.5 then setpoint offset would be 5 mV.

It is to be understood that while a certain form of the invention is illustrated, it is not to be limited to the specific form or arrangement of parts herein described and shown. It will be apparent to those skilled in the art that various changes may be made without departing from the scope of

the invention and the invention is not to be considered limited to what is shown and described in the specification and drawings.